# PSCR 2020:

## THE DIGITAL EXPERIENCE

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# Access Driven Modified Rhyme Test Intelligibility

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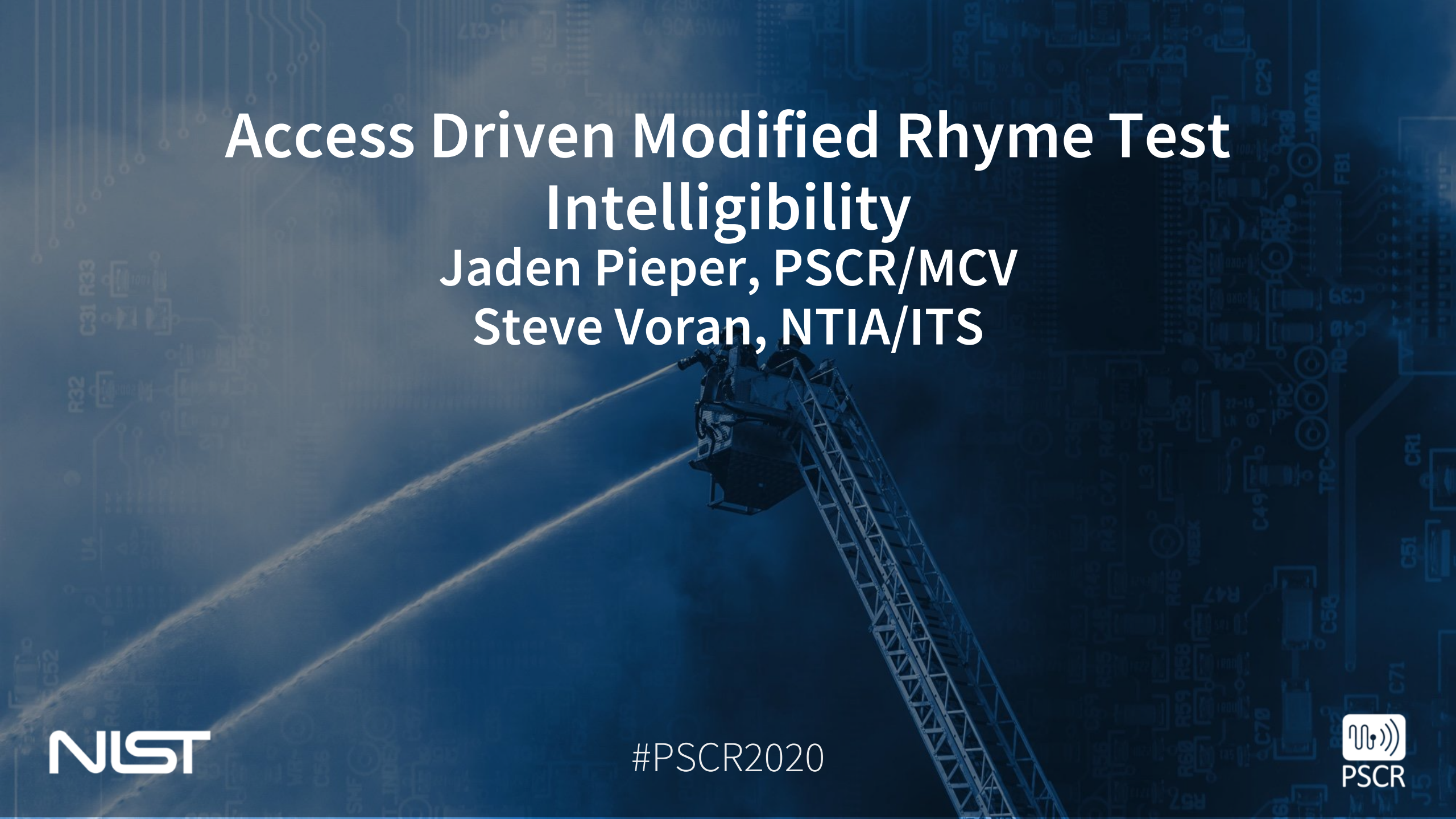

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# Overview

- Quality of Experience Based Measurements
- Access Time Measurement System
- Intelligibility
- New Audio Files
- New MRT Application
- Path Forward

# Quality of Experience Based Measurements

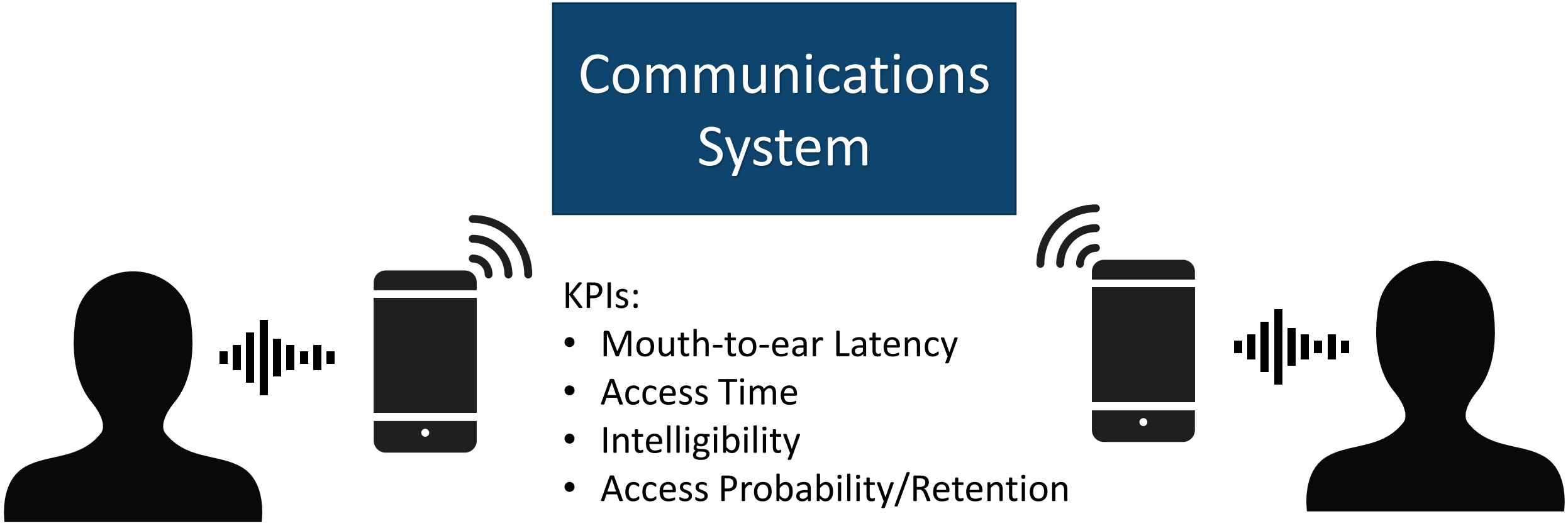
- **QoE KPIs for Mission Critical Voice (MCV)**
  - Mouth-to-Ear Latency
  - Access Time
  - Voice Quality/Intelligibility
  - Access/Retention Probability
- **MCV QoE Measurement Methods Presentation**
- **Mouth-to-Ear Latency Measurement System**
- **Access Time Measurement System**

# The User Experience: PTT Communications

- **Press PTT and speak into a device**
- **Listening to speech output from a device**
- **It's all about speech**

- **Goal - Create measurement systems that are:**
  - Based upon the user experience -- speech
  - Comparable and fair across technologies
- **This is not:**
  - Diagnosing internal components of specific systems

# Technology Agnostic Measurements



# User Driven Access Definition

- **End-to-end Access Time**
  - *The total amount of time from when a transmitting user first presses PTT until a receiving user hears intelligible audio.*
- **Two Components:**
  - Mouth-to-ear Latency
    - *The time between speech being input into one device and its output through another*
  - Access Delay
    - *The minimum length of time a user must wait between pressing a PTT button and starting to speak to ensure that the start of the message is not lost*

# Formalizing Access Delay

- **Access Delay**
  - All about if a message is lost or not
  - Intelligibility is the key to the measurement
- **Formal Definition:**
  - *The minimum length of time a user must wait between pressing a PTT button and starting to speak to ensure that the first word of the message has an average intelligibility that is no lower than* $\alpha \cdot I_0$
  - $0 < \alpha < 1$, defines acceptable intelligibility level
  - $I_0$ is the baseline intelligibility of that word through the communications system
    - No system is perfectly intelligible
    - Some level of degradation almost always present

# Intelligibility

- **Modified Rhyme Test (MRT)**
  - Used to test intelligibility of SCBA masks[1]
  - Batches of six words
    - *went, sent, bent, dent, tent, rent*
    - Words: consonant-vowel-consonant
    - Each batch: Either leading or trailing consonant varies
  - MRT Trial
    - Carrier phrase + word
    - e.g. “Please select the word *went*”
    - Success (identified) or Failure (mis-identified)
  - Over lots of trials scores are generated
    - Score is value between 0 and 1
    - Corrected for guessing
  - High time cost

1: NFPA 1981 Standard on open-circuit self-contained breathing apparatus (SCBA) for emergency services (2007)

# Intelligibility

## MRT: Standard Use Case Examples

**Batch:** ***fun, sun, bun, gun, run, nun***
**Distortion: Background noise + system**

- **Extreme** 
- **Moderate** 
- **Mild** 
- **None** 

# Intelligibility

- **Articulation Band Correlated Modified Rhyme Test (ABC-MRT)**
  - Objective algorithm to provide estimates of true MRT scores
  - Most recent version is ABC-MRT16
  - Relies on temporal correlations within articulation index bands
    - Break speech into a “musical score”
    - Representation of speech in time and frequency
  - Costs: Cheaper and faster
    - Relatively low time cost
      - Can get estimated MRT scores “on demand”
    - Much lower infrastructure cost

# Measurement Concept

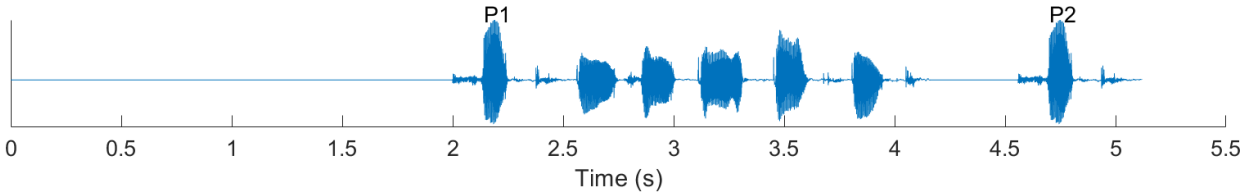
Overview

- **Access Delay definition:**
  - *The minimum length of time a user must wait between pressing a PTT button and starting to speak to ensure that the first word of the message has an average intelligibility that is no lower than* $\alpha \cdot I_0$
- **Repeatedly send pre-defined audio clips through communications system**
- **Vary where in the clip PTT is triggered**
- **Measure relationship between PTT time and intelligibility of the first word in the clip**
  - No more carrier phrase
  - Starting to move outside intended scope of ABC-MRT16

# Measurement Concept

Audio Clips

- **Select single word from ABC-MRT16 database[1]**
  - Use only words from batches where leading consonant varies
    - E.g. *went, sent, bent, dent, tent, rent*
    - Places majority of intelligibility emphasis on beginning of word
- **Structure:**
  - $T$ seconds of silence
  - Play word, $P_1$
  - $T$ seconds of speech
  - Play word again, $P_2$

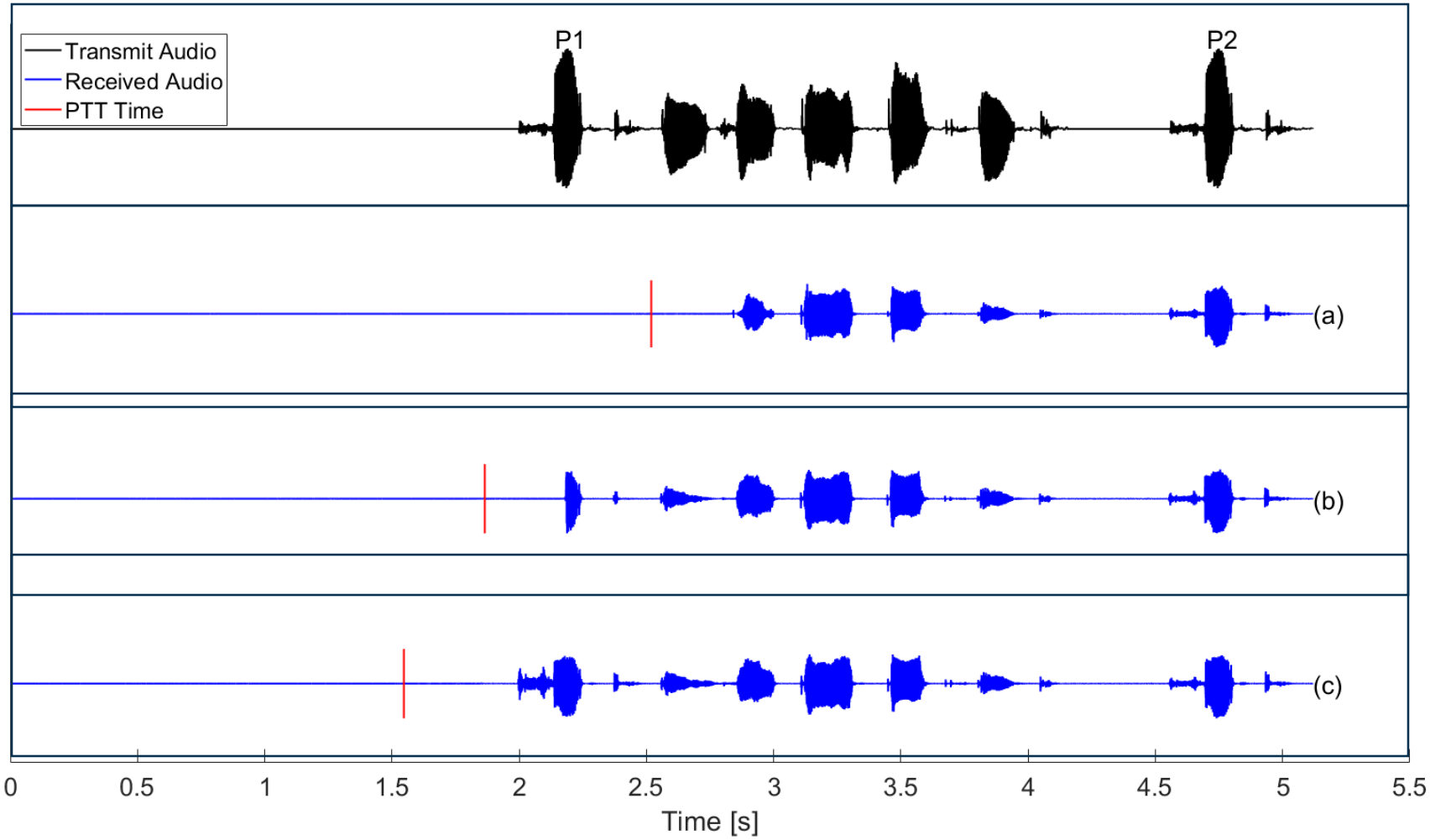



- **$T$ chosen so that system access time is less than $T$ seconds**
- **Intelligibility of $P_2$ describes the asymptotic intelligibility, $I_0$**
- **Intelligibility of $P_1$ relates PTT time with intelligibility**

1: Voran SD (2017) A multiple bandwidth objective speech intelligibility estimator based on articulation index band correlations and attention. 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp 5100–5104.doi: 10.1109/ICASSP.2017.7953128

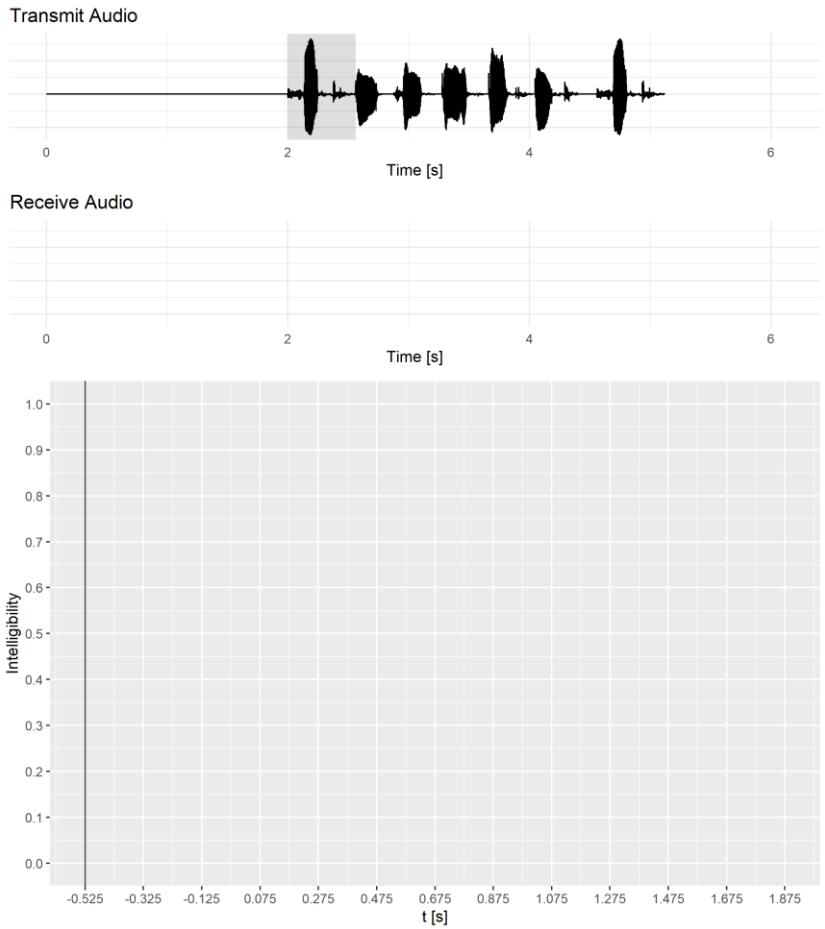
# Measurement Concept

Intelligibility Examples: *hook*



# Access Time

***Play Access Animation Here***



# Measurement Limitations

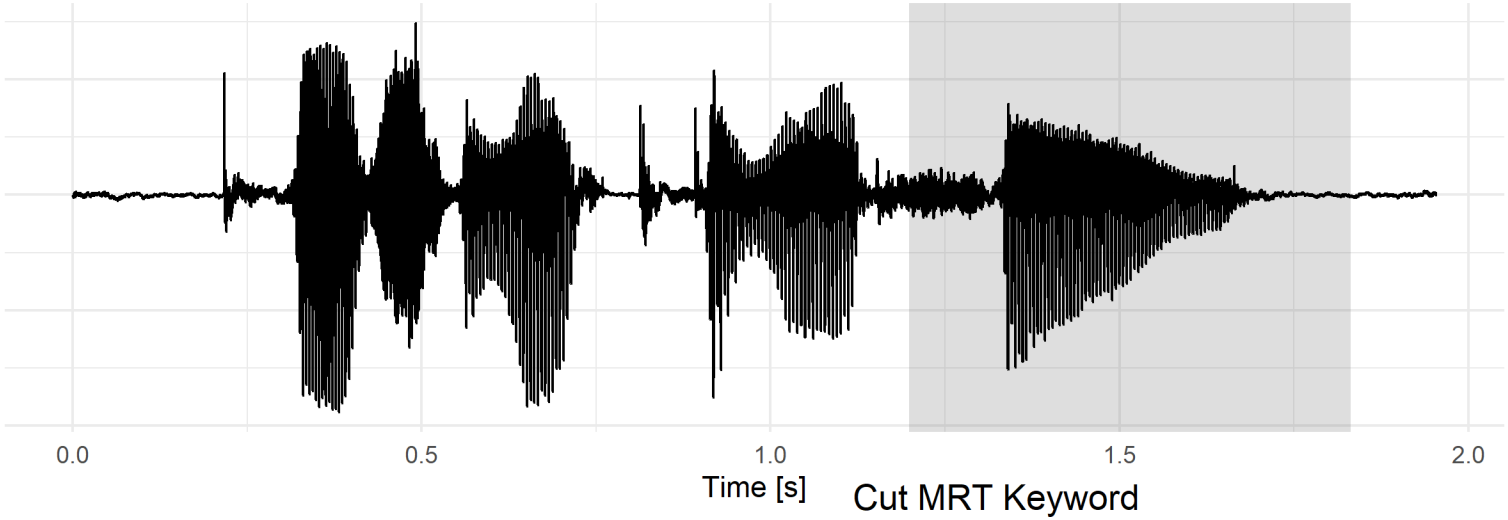
- **MRT keywords not designed for this focus**
  - MRT keywords extracted from full MRT phrases
  - “Please select the word west”
  - Coarticulation
- **ABC-MRT not designed for this impairment**
  - ABC-MRT designed around normal MRT impairments
  - Not designed with partially muted words in mind
  - Data does not exist
  - Can not guarantee response mimics human’s
- **Need to run new MRT experiments**
  - Focus on partially muted words

# Beginning of MRT Keywords

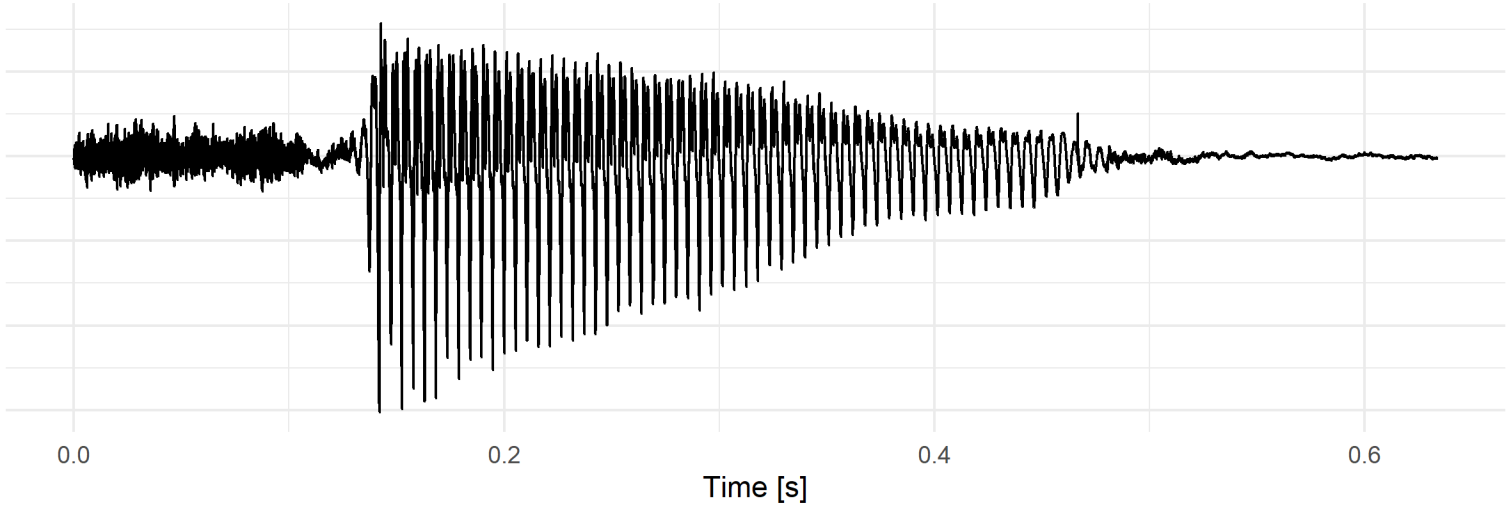
- **Beginning of the word**
  - Key to access delay measurements
  - Built into the definition
    - *The minimum length of time a user must wait between pressing a PTT button and starting to speak to ensure that the first word of the message has an average intelligibility that is no lower than* $\alpha \cdot I_0$
- **How do you determine the start of the keyword?**
  - Extract from recorded MRT speech
  - “Please select the word west”

# Extracting MRT Keywords

Full MRT Phrase

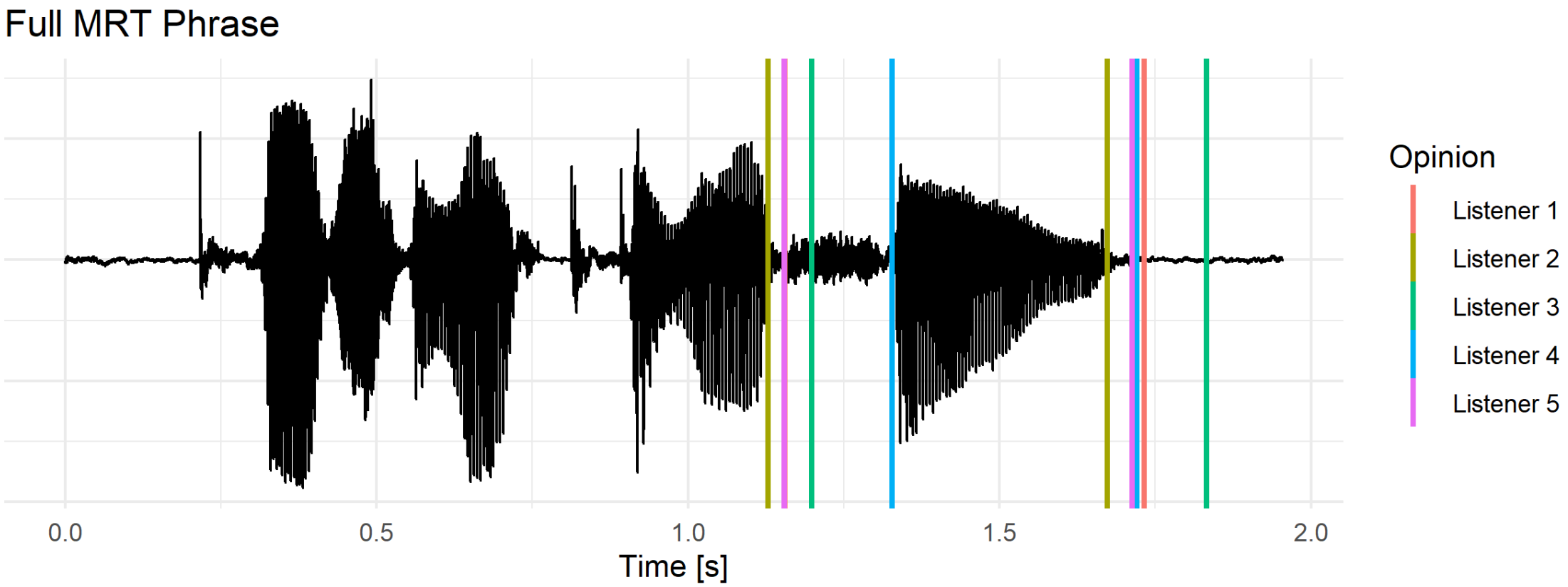



Cut MRT Keyword




# Extracting MRT Keywords

- **Get multiple opinions**



# New Audio

- **Extracting coarticulated speech is hard**
- **Design speech for this problem from the ground up**
  - Isolate keywords
  - Knowledge of when a talker is speaking

# New Audio

# New Audio

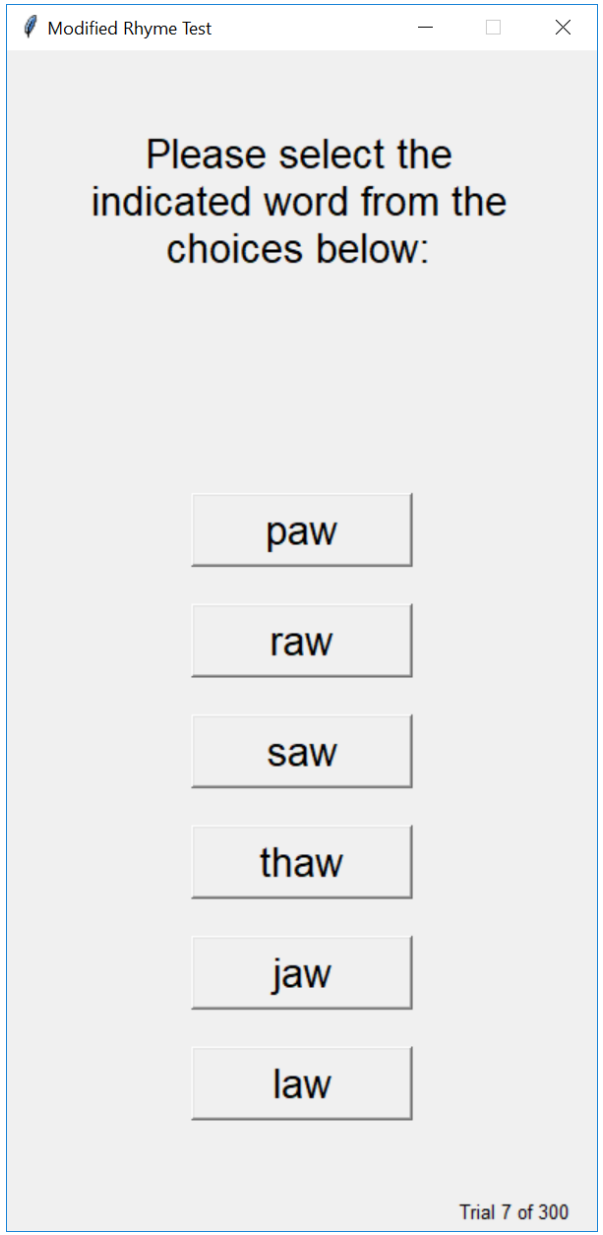
- **Four talkers**
- **300 MRT keywords**
  - 1 second of “silence” between keywords
- **Carrier phrase 3 times**
  - Beginning, middle, end
- **List of 10 Harvard Phrases**
  - Phonetically balanced
  - Good audio for mouth-to-ear latency measurements
  - “Hoist the load to your left shoulder.”

# New Audio: Extracting MRT Keywords

- **Talker PTT**
  - Identify when talkers think word is spoken
  - Quick reference for extracting MRT keywords
  - Large gaps between PTT and speech
  - Limited scope for conclusions
- **Manual Corrections**
  - Talkers made mistakes
  - Verify each word

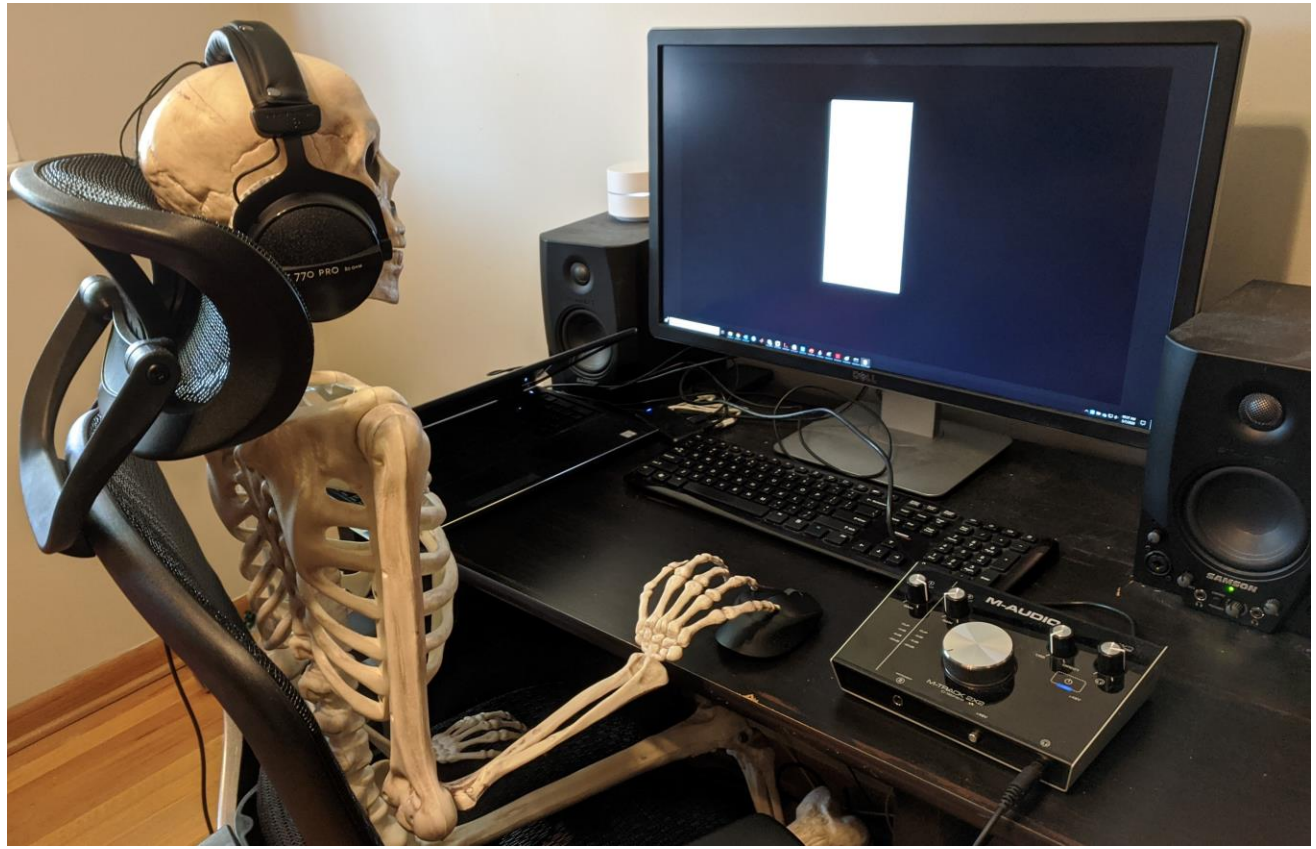
# MRT Application

- **ITS MATLAB GUI**
  - Built in 2007
  - Requires license
- **Open source MRT application**
  - Could not find any
- **Design new MRT application**
  - Free and easy to use
  - Python



# Verify Baseline Intelligibility

- **Test Design**
  - Five Listeners
  - 4 sessions each
  - 300 trials per session
- **Components**
  - Isolated room
  - Sound isolation - closed studio headphones
  - Audio interface



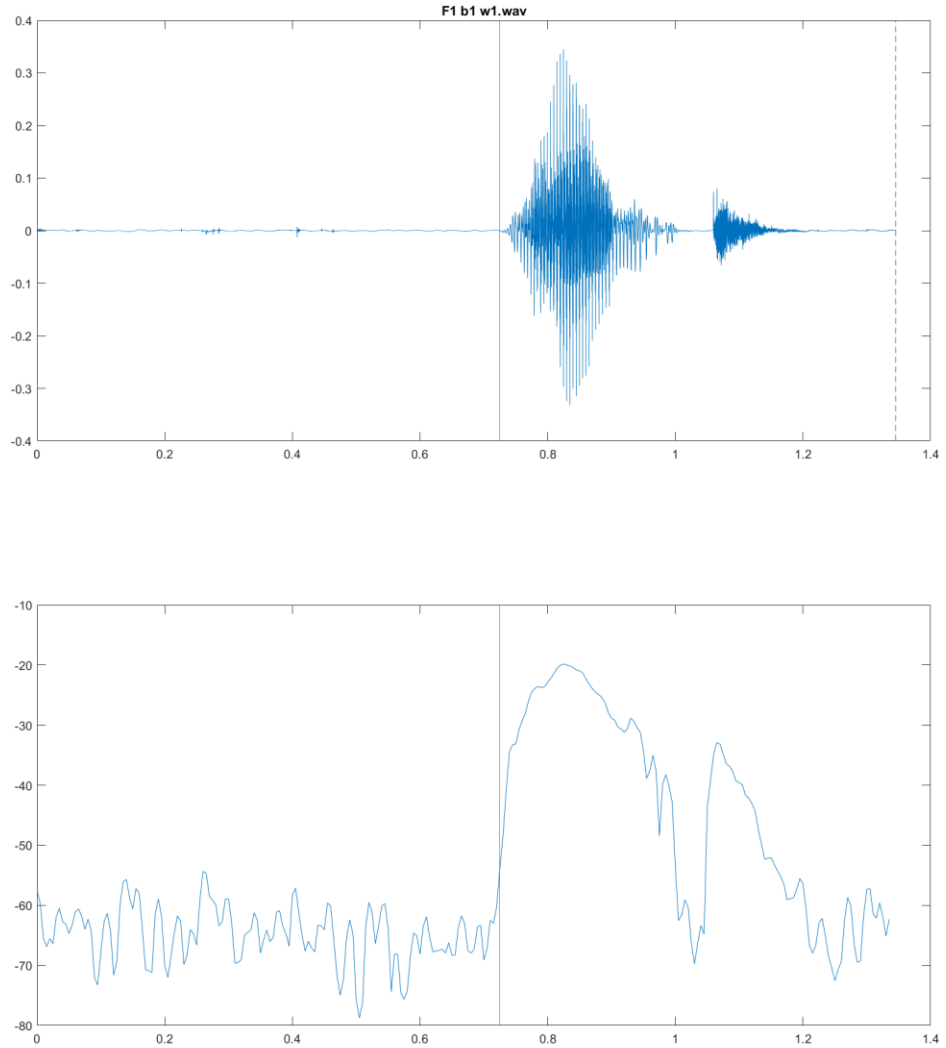
# Verify Baseline Intelligibility

- **Baseline intelligibility: 99.1%***
  - *Audio issues
- **Expect results to improve**

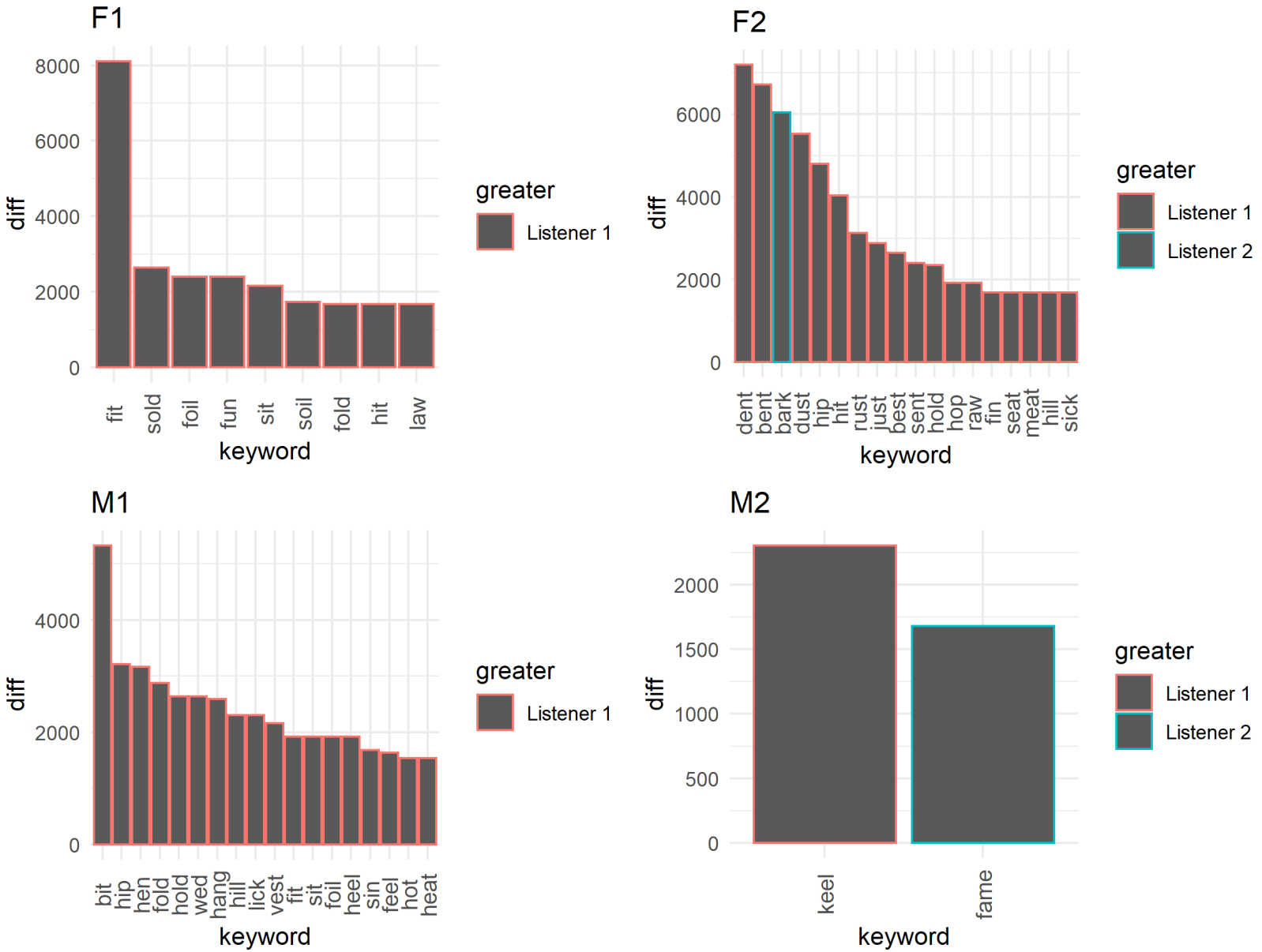
| Talker | Score |
|---|---|
| F1 | 99.0% |
| F2 | 99.1% |
| M1 | 98.9% |
| M2 | 99.3% |

# Identify Start of Audio

- **Accuracy decreases cost of human MRT trials**
- **Simple MATLAB application**
  - Process much faster
- **Essentially quantizes selections**
  - Should cause more agreement
- **Still disagreement**



# Identify Start of Audio

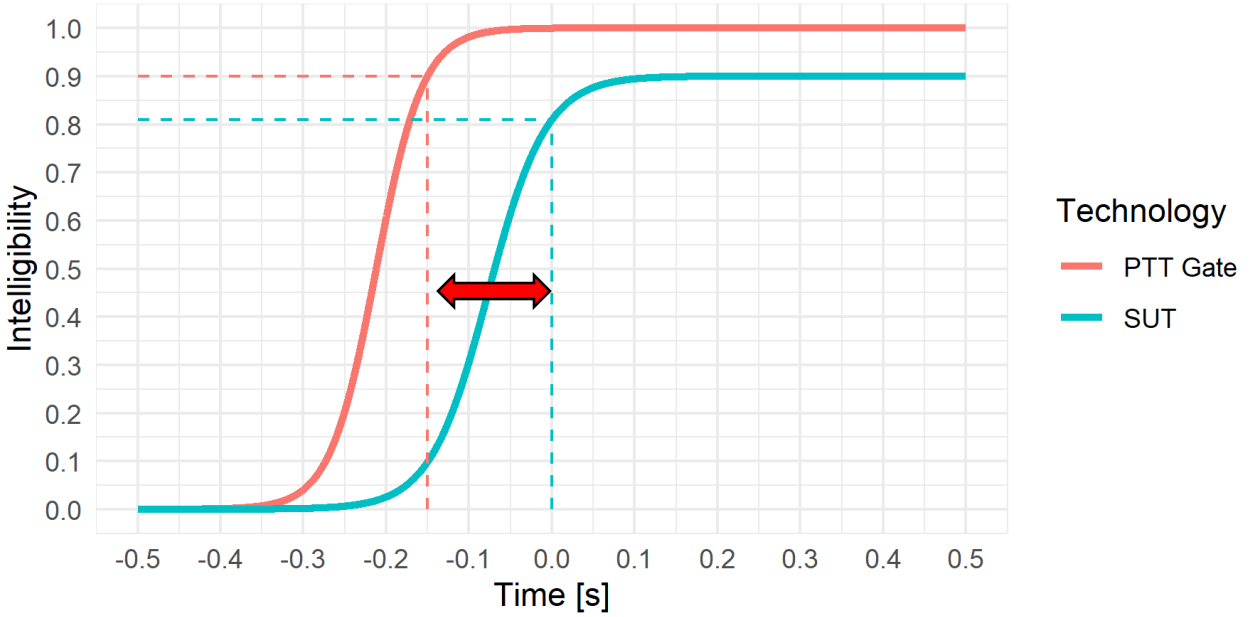


# Start of Word Correction Factor

- **Choose a single word**
- **Fix $\alpha$**
  - $\alpha = 0.9$ for now, 90% intelligibility point
- **Calculate access reference point**
  - Using analog switch (PTT Gate) calculate $\tau_{pg}(\alpha)$
  - How much of the beginning of the keyword clip can be cut
  - PTT Gate access delays are always negative by definition
  - Expendable audio
  - Critical point within a word
- **For a given system-under-test (SUT) calculate $\tau_{sut}(\alpha)$**
  - Time between PTT and starting the keyword clip to achieve 90% intelligibility
- **Calculate true access delay as $\tau(\alpha) = \tau_{sut}(\alpha) - \tau_{pg}(\alpha)$**
  - Time between PTT and keyword clip for 90% intelligibility
  - Corrects for time in keyword clip irrelevant to 90% intelligibility

# Start of Word Correction Factor

- **Fix $\alpha = 0.9$**
- **Think about the word "hook"**
  - Long "h" sound, takes up 200 ms
  - Need 100 ms to understand "hook" from "took", "look", etc…
  - Bad start selection, 50 ms of silence at beginning
- $\tau_{pg}(\alpha) = -150$ ms
- $\tau_{sut}(\alpha) = 0$ ms
  - System required 0 ms between PTT being pressed to send "hook" with 90% of asymptotic intelligibility
  - Currently: no access delay
  - Know that the first 150 ms of the audio clip "worthless"
- $\tau(\alpha) = \tau_{sut}(\alpha) - \tau_{pg}(\alpha) = 0 \ - -150 = 150$ ms
  - Captures the "truth" better
  - System needs 150 ms of setup time to send "hook" through intelligibly



# Future Work

- **Baseline intelligibility**
  - Redo some sessions
- **Access MRT experiment**
- **New speech intelligibility estimation algorithm**
  - Focused on partially muted word impairment

# New MRTs: Design Plan

- **MRT lists**
  - 8 lists
  - 6 words per list
- **Vocoders**
  - Analog
  - P25
  - AMR
- **Cuts**
  - 40 ms intervals

# Creating New Intelligibility Estimation Algorithm

- **Compute accuracy of ABC-MRT16 access delay system**
- **Develop specialized intelligibility estimator**
  - Focused on partially muted words
- **Develop algorithm to differentiate intelligibility on a more fine tuned scale than whole words**
  - One-to-one measurement
  - Requires fine time resolution

# Related Talks

- **PSCR 2020: The Digital Experience**
  - MCV QoE Measurement Methods Presentation
- **2019 Annual Public Safety Broadband Stakeholder Meeting**
  - Mission Critical Voice Quality of Experience Speech-Based Access Measurement

# Related Publications

- Mission Critical Voice Quality of Experience Access Time Measurement Methods
- Mission Critical Voice QoE Mouth-to-Ear Latency Measurement Methods

# THANK YOU

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